Name : ______ANSWER KEY__________________

Team #: ________________________

Name : ____________________________________

School: _________________________

Event and Construction Requirements

☐ 1. Competitors construct only 1 device
☐ 2.a. Reference materials secured in 3 ring binder
☐ 2.a. Competitors bring up to 2 calculators
☐ 2.b. Device, 2 beakers and charts impounded
☐ 2.e. Competitors wear eye protection during testing
☐ 2.f. Competitors must be able to answer questions about the device per the Building Policy
☐ 3.a. No asbestos, mineral wool, fiberglass in device
☐ 3.b. Division B: device fits in 20.0 x 20.0 x 20.0cm box
☐ 3.c. Division C: device fits in 15.0 x 15.0 x 15.0cm box
☐ 3.d. Beaker can be inserted/removed from device
☐ 3.e. Device has >=1.5cm diameter hole above beaker
☐ 3.e. Top of hole <12cm inside beaker bottom
☐ 3.e. Hole must remain open during competition
☐ 3.f. Device has no energy sources
☐ 3.g. Device not significantly different from room temp

Graphs / Tables (each item can get 0 – 2 points)

Data spans one variable range ________

At least 10 data points ________

Proper labeling (e.g. title, name, units) _______

Number of graphs/tables (x 0.5 points) _______

Labeled device picture/diagram _______

Chart Score (CS): ________

Penalties

Competition violations(s)	Y	N
Team didn't bring a device	Y	N
DQed for unsafe operation	Y	N
Construction violations corrected	Y	N
Missed impound	Y	N

Test Score (back page) (TS) ___________

Temperatures (in degrees Celsius)

Start ___________ Room __________

Predicted temperature (PT) __________

Final internal beaker (FI) __________

Final external beaker (FE) __________

Water (ml) _________ Ice water (ml) __________

Ice Water Bonus (ml/10) (IWB) ________

Heat Retention Factor (FI/FE) ________

Highest Heat Retention Factor (HHRF) ________

Heat Score (HRF/HHRF x 15) (HS) ________

Prediction Est. (1-|(FI-PT)/FI|) (PE) ________

HighestPrediction Estimate (HPE) ________

Prediction Score (PE/HPE x 25) (PS) ________

Team Verification

4.h. I verify the event supervisor has reviewed with me my team's recorded device testing data

Signature:

____

Final Score (TS+CS+HS+PS+IWB)

Names : ________________________________ School: _____________________ Team #: ____

History of Thermodynamics

Write the corresponding letter next to the date in the column below. (1 pt each, max 10)

1.	D	1650	A	The word "enthapy" is first used to describe energy in a thermodynamic system
2	F	1697	B	Celsius scale set to 0 (freezing) and 100 (boiling)
3	H	1724	C	William thomson (Lord Kelvin) defined the need for an absolute zero
4	B	1743	D	Otto von Guericke designed and built the world's first vacuum pump
5	E	1824	E	Sadi Carnot published "Reflections on the Motvie Power of Fire"
6	C	1848	F	Thomas Savery built the first engine
7	G	1850	G	Rudolf Clausius coined the term "entropy"
8	J	1876	H	Fahrenheit scale proposed
9	A	1909	I	Kelvin scale defined as line from absolute zero and triple point of water
10	I	1954	J	Gibbs free energy equation

Temperature Scales and Conversion

11 – 26 In the table below, each row is equal. Fill in the missing numbers. (1 pt each, max 16)

Celcius	Delisle	Fahrenheit	Kelvin	Newton	Rankine	Reaumur	Romer
-273.15	559.73	-459.67	0	-90.14	0	-218.52	-135.90
-17.78	176.67	0	255.37	-5.87	459.67	-14.22	-1.83
-14.29	171.43	6.29	258.864	-4.71	465.96	-11.43	0
0	150	32	273.15	0	491.67	0	7.5
20	120	68	293.15	6.6	527.67	16	18
100	0	212	373.15	33	671.67	80	60

Thermodynamic Laws

Write the corresponding letter next to the date in the column below. (2 pt each, max 16)

	Answer	Law		Definition
27	E	Zeroth law	A	the change in the internal energy ΔU of a closed system is equal to the amount of heat Q supplied *to* the system, minus the amount of work W done *by* the system on its surroundings
28	A	First law	B	The state of a simple compressible system is completely specified by two independent, intensive properties
29	D	Second law	C	When the pressure on a sample of a dry gas is held constant, the Kelvin temperature and the volume will be directly related
30	F	Third law	D	the total entropy can never decrease over time for an isolated system
31	H	Boyle's law	E	*If A is in thermal equilibrium with B and if B is in thermal equilibrium with C, then A is in thermal equilibrium with C*
32	C	Charles' law	F	The entropy of a perfect crystal at absolute zero is exactly equal to zero
33	G	Dalton's law	G	a mixture of non-reacting gases, the total pressure exerted is equal to the sum of the partial pressures of the individual gases
34	B	State Postulate	H	For a fixed amount of an ideal gas kept at a fixed temperature, pressure and volume are inversely proportional

Theromdynamics Concepts

Circle the most appropriate answer for each question (2 pts each, 12 max)

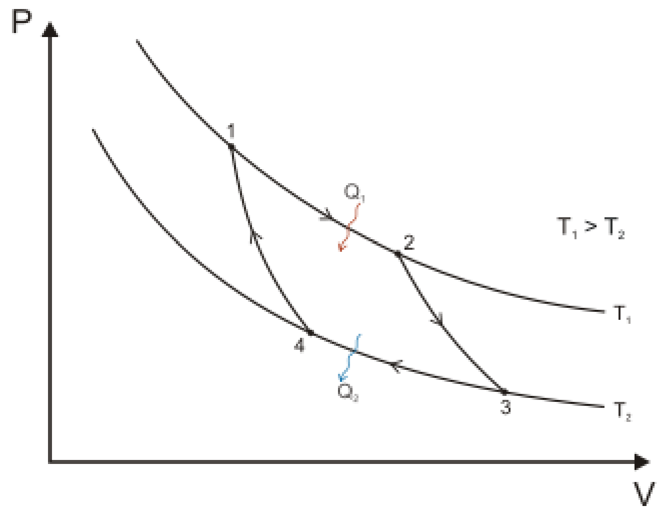
35. Which of the following is NOT a mode for heat transfer:
    a. Conduction
    b. Radiation
    c. Retention
    d. Convextion
    e. All of the above
    f. None of the above

36. Entropy can be best be defined as::
    a. Measure of heat capacity of a system
    b. Degree of disorder in a system
    c. Amount of heat transfered by a system
    d. Extent a system is open or closed
    e. All of the above
    f. None of the above

37. The ideal gas law implies:
   a. PV/T = constant
   b. Initial (PV/T) = Final (PV/T)
   c. PV = nRT
   d. R = PV/T divided by numebr of moles
   e. All of the above
   f. None of the above

38. Heat capacity divided by unit mass is equal to:
   a. Latent heat
   b. Enthalpy
   c. Energy
   d. Conductivity
   e. All of the above
   f. None of the above

Questions 39 & 40 pertain to the graph at the right.



39. This graph represents:
   a. Brayton cycle
   b. Carnot cycle
   c. Ericsson cycle
   d. Rankine cycle
   e. All of the above
   f. None of the above

40. The line segment 2-3 is best described as:
   a. Isothermal Expansion
   b. Adiabatic Expansion
   c. Isothermal Compression
   d. Adiabatic Compression
   e. All of the above
   f. None of the above

<u>Thermodynamic Problems</u>

Answer the following problems in the space provided. Show your work for potential partial credit. (46 pts max)

41. A heat engine rejects waste heat to a nearby lake at a rate of 20kW. The lake's temperature is 12C, and the outside temperature is 20C. The engine is operating on a Carnot cycle with a thermal efficiency of 80%. Determine the power output of the engine and the temperaure of the source, in C. (10 pts)

Qh= W + Qc, n = W / Qh ---> W = (n Qc) / (1 – n) ---> .8 * 20 / (1-.8) = 80kW

or

80% = 1 – Qreject/Qsupply --> 1-.8 = 20/Qsupply ---> Qsupply = 100 MW --> W = 100 – 20 = 80kW

n = (Th – Tc)/Th ----> Th = Tc / (1 – n) ---> (273.15 + 12) / (1 - .8) = 1424.75 K = 1152.6 C

1/2 credit for either power or temp, full for both

42. A mass of 15 kg gains 98.0 kJ of heat when its temperature increases 32F to 68F. Determine the specific heat of the mass. (10 pts)

68F = 20C, 32F = 0C
Q = c m dT -----> 98.0 kJ = c (15 kg) (20C – 0C)
c = 0.327 kJ/(kg K) Also acceptable = 327 J/(kgC)

1/2 credit for identifying correct equation to use

43. A piston-cylinder device has a volume of 2 liters at 15C and 1 atmosphere. The pressure inside increases by 10 kPa and the temperature by 5C. Determine the new volume inside the piston-cylinder. (10 pts)

15C = 288.15K
1 atm = 101325 = initial P
101325 + 10,000 = 111325 final P

(PV/T) initial = nR = (PV/T) final ----> (101325 x 1) / 288.15 = (111325 V / (288.15+5)
V = 0.926 L, or 926 mL

1/2 credit for identifying correct equation to use

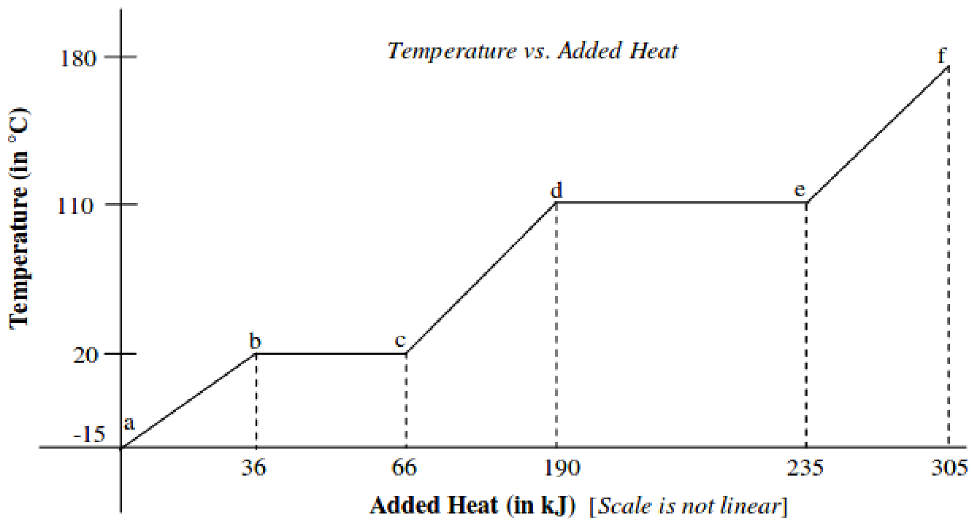
44. Insulation with a conductivity of 0.5 W/m*K has a thickness of 25mm. The insulation is replaced with 30mm thick insulation that has a conductivity of 0.45 W/m*K. Will the new insulation be more effective (save energy) or be less effective (lose energy)? Explain answer and determine by how much (% better or worse)? (6 pts)

Conduction = q = -k A dT/dx ---> q old = .5 / .025 x A x dT = -20 A dT
q new = 0.45 / .030 A dT = -15 A dT
(20 – 15) / 20 = .25 or 25%

New insulation will be LESS effective by 25% of the original

1/3 credit for identifying conduction equation
1/3 credit for calculating number x A x dT
1/3 credit for percentage
0 credit for just stating "Less"

For questions 45 & 46, consider the following. A 10-g material is studied to understand it's phase changes. The graph below shows the transition from gas to solid.



45. At what temperature does the material melt? (4 pts)

20C

46. What is the latent heat of vaporization? (6 pts)

Q = L m ---> (235 – 190) kJ = L (0.010) kg ---> L = 4500 kJ/kg
1/2 credit for identifying correct equation to use

47. How much heat is required to raise the substance from 20C to 110C. Explain your answer. (6 pts)

It will take at least 124 kJ, depending on what state the substance is in. At most, from completly solid, it will take 154 kJ.

1/2 credit for either number, full credit for both

48. A 5 kg rock is heated to 200C and then placed into a 20C bucket of water. If the bucket contains 50 kg of water, what temperatuer will the water be once it reaches equillibrium? Assume the rock has a specific heat of 0.8 kJ / (kg K). (6 pts)

Tfinal = (m1 cp1 t1 + m2 cp2 t2) / (m1 cp1 + m2 cp2)

(5 kg 0.8 kJ/(kg K) 473.15 K + 50kg 4.186 kJ/(kg K) 293.15 K) / (5 x .8 + 50 x 4.186) =
1892.6 + 61,356.295 / (4 + 209.3) = 296.525 = 23.4

1/2 credit for identifying proper equation

Score (S):	Highest Score (HS):	**Test Score (S/HS x 45):**